NASA LANGLEY RESEARCH CENTER,
8-FOOT HIGH SPEED WIND TUNNEL
Hampton (Independent City)
~~Hampton County~~
Virginia

HAER No. VA-118-B

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

Historic American Engineering Record
National Park Service
U.S. Department of the Interior
1849 C St., NW Room NC300
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HISTORIC AMERICAN ENGINEERING RECORD

NASA LANGLEY RESEARCH CENTER, 8-FOOT HIGH SPEED WIND TUNNEL

HAER NO. VA-118-B

Location:	Adjacent to 640 Thornell Avenue, on Back River Road; NASA Langley Research Center, Hampton, Virginia
UTM Coordinates:	USGS Universal Transverse Mercator Coordinates:

	Northing	Easting
A	4104818.90	380804.20
B	4104765.10	380763.17
C	4104779.75	380739.78
D	4104833.48	380766.84

Quad: Hampton, Virginia, 1:24000

Dates of Construction:	1936, 1945, 1950
Engineers/Designers:	Russell O. Robinson and Manley J. Hood; Concept for the tunnel first suggested by Eastman N. Jacobs.
Present Owner:	National Aeronautics and Space Administration (NASA) Langley Research Center Hampton, Virginia 23665-5225
Present Use:	Deactivated in 1961, some components reused in other facilities; converted to offices and storage areas.

Significance:

The facility was authorized in July 1933 and built by the Public Works Administration for $266,000. It tested complete models of aircraft and aircraft components in a high-speed airstream approaching the speed of sound. Originally capable of testing at Mach 0.75, it was repowered in the 1940s and early 1950s to have a Mach 1.2 potential.

The most important contribution of the HST was defining the causes and cures for the severe adverse stability and control problems encountered in high-speed dives. This tunnel also produced the high-speed cowling shapes used in World War II aircraft, and efficient air inlets for jet aircraft. The first 500-MPH analyses of propellers were made here early in the war. After repowering, the 8-Foot Tunnel produced precise transonic data up to Mach numbers as high as 0.92 for such aircraft as the X-1, D-558, and others. Its final achievement was the development and use in routine operations of the first transonic slotted throat.

The investigations of wing-body shapes in this tunnel led to Richard Whitcomb's discovery of the transonic area rule. The HST developed an impressive record in aviation history as an example of accomplishment by imaginative researchers.

Project Information:

This documentation was initiated July 17, 1995 in accordance with a Memorandum of Agreement with the National Aeronautics and Space Agency and the National Park Service.

This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering and industrial works in the United States. The HAER program is administered by the Historic American Buildings Survey / Historic American Engineering Record Division (HABS/HAER) of the National Park Service, U. S. Department of the Interior. The National Aeronautics and Space Administration (NASA) - Langley Research Center Recording Project was cosponsored during the summer of 1995 by HABS/HAER under the general direction of John Burns, Deputy Chief, and by the Langley Research Center, Paul F. Holloway, Director.

The field work, measured drawings, historical reports, and photographs were prepared under the direction of Eric N. DeLony, Chief, HAER, and project leader Dean A. Herrin, PhD. The recording team consisted of Charissa Y. Wang and Donald M. Durst, Principals/Partners - Hardlines: Design & Delineation. Robert C. Stewart, Industrial Archaeologist, West Suffield, CT produced the historical report. Jet Lowe, HAER, was responsible for large-format photography.

Others who have contributed their time, advice, documents and help were: Brad Ball (GIS Team Leader); Cyler W. Brooks Jr. (ADYD Transonic Aerodynamics Branch); Charlie Debro (FST Building Coordinator); Dana Dunham (FST); Charles D. Hsrris (ADYD Transonic Aerodynamics Branch); Ron Harvey (Langley Research Center Public Affairs Office); Rick Hoff (LaRC Photo Lab); Richsrd Layman (Historical Program Coordinator); John Mouring (Facilities Systems Engineer); Gene Nutall (Towing Tank Supervisor); Bill Salyer (LaRC Photo Lab). Jay Waravdekar, GIS Analyst, provided the UTM coordinates for the facility.

Historian: Robert C. Stewart January 1995

For additional NASA Langley Research Center information see:

HAER No. VA-118-A - NASA Langley Research Center, Full-Scale Wind Tunnel

HAER No. VA-118-C - NASA Langley Research Center, Seaplane Towing Channel

HAER No. VA-118-D - NASA Langley Research Center, 8-Foot Transonic Pressure Tunnel

CONTENTS

Introduction:

The 8-Foot High Speed wind tunnel at NASA's Langley Research Center occupies a distinguished position in the annals of aerospace history. It was NACA's first high-speed tunnel sizable enough to test large scale models of complete aircraft on a continuous basis. Stability and control problems experienced in high-speed dives were first analyzed at this facility. Research data from this tunnel was essential in the design of the high-speed cowlings of World War II aircraft. Cowling shapes for early jet aircraft were created with criteria from tunnel research. Research in the 8-Foot HST investigated the first 500-MPH propellers. As technology advanced, the 8-Foot tunnel was redesigned and repowered to produce transonic and supersonic test data on new designs. The facility's final accomplishment was in the development and routine use of the first transonic slotted throat. Investigations which used the slotted throat led to the discovery of the transonic area rule for designing supersonic aircraft. The 8-Foot high-speed tunnel, redesignated the 8-Foot transonic tunnel (TT), had sn impressive record as a valued aerodynamic research tool by the time it was deactivated in 1956.

Historical Overview:

After the first phsse of aviation research which refined aerodynamic knowledge and applied it to practicsl sircraft design, the emphssis turned to building aircraft cspable of ever higher speed capability, generating a new arrsy of research challenges. The problems to be encountered with high speed were first noticed in propellers. Esrly propeller tests showed thst when rotating propeller tips exceeded Mach 0.9[a], efficiency dropped off. It was also apparent that with higher powered engines, efficient cowling patterns, retractable landing gear and genersl improvement in wing design, that high-speed effects would begin to affect other sircraft components.

On the theoretical side, experiments at the Edgewood, New Jersey Arsenal developed supersonic airspeeds in a free-jet machine having a convergent-divergent nozzle. L. J. Briggs and Hugh L. Dryden reported that as an airstream approached the speed of sound, it underwent extreme changes in behavior. 8reaking the "sound barrier" challenged the engineers[b].

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[a]The Mach number expresses the ratio of aircraft speed to the speed of sound. The speed of sound in air at sea level is about 741 miles per hour, so an aircraft flying at Mach 0.8 would be traveling at about 593 miles per hour. It was named for Ernst Msch, sn Austrian engineer who investigsted high-speed phenomens.

[b]In 1935, a newsman asked 8ritish aerodynamicist W.F. Hilton what problem he was working on in the National Physical Laboratory's newest high-speed wind tunnel. Pointing to an airfoil drag plot, Hilton replied, "See how the resistance of a wing shoots up like a bsrrier against higher speed as we approach the speed of sound." The next morning, all the leading English dailies misrepresented Hilton's response by coining the phrase, "the sound

The existing tunnels at Langley were limited to speeds under 100 m.p.h. and electric power sufficient to operate a high-speed tunnel was unavailable. In 1927 NACA built an 11-inch tunnel induction-drive high-speed wind tunnel. The airstream was provided by rapidly releasing air from the variable density tunnel (VDT) which served as a high-pressure reservoir[c].

Eastman Jacobs and John Stack supervised the experiments using Langley's original high-speed induction tunnel[d]. The tunnel produced air velocities in excess of 500 m.p.h. While not intended to investigate high-speed flight, the tunnel broadened the experience of Langley's engineers in transonic aerodynamics. Among diacoveries relating to compresaibility phenomena, they discovered information that was useful in developing designs for a high-speed tunnel. A second tunnel built in 1934, with a throat of 24-inches, provided speeds of 765 m.p.h. While the tunnels produced useful data, the capacity of the VDT tank limited test times to less than a minute. Also, the tunnel diameters limited model sizes. A large high-speed tunnel capable of sustained operation with sizeable models was essential to continue research.

The director of research at Langley, George W. Lewis, believed that a high speed tunnel would "make possible the use of great speeds with safety, and thus give the United States a decided advantage over other nations."[1] Eastman Jacobs developed the concept in November 1933. The facility became known as the 8-Foot High-Speed Tunnel (HST).

Design Features - 8-Foot High Speed Tunnel

The 8-Foot High-Speed Tunnel (HST), was built near Back River during the Great Depression by Work Progress Administration (WPA) laborers at a cost of $266,000. Reinforced concrete was selected as the material of construction because it was inexpensive and capable of being molded by workers employed by the Works Projects Administration. WPA workers were characterized by widely divergent skills and degrees of experience. The structure is a single-return, atmospheric, closed concrete tube shaped into a hollow elongated ring. It has an interior which tapers from a maximum diameter of twenty-four feet to a minimum of eight feet at the closed test section. The tunnel went on stream in 1936 under National Advisory Committee for Aeronautics (NACA) control.

This project was also the world's first, large size high speed tunnel. Models having a six-and-a-half foot wing span could be tested. An 8,000 horsepower fan provided a continuous airstream. After minor modifications, the

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barrier" (Hansen 1987:253).

[c]This was a "blowdown" tunnel. Blowdown tunnels use a jet of air from a pressurized reservoir to create the airstream.

[d]Induction tunnels use a stream of air flowing into a vacuum chamber to generate the airstream.

engineers found that they could achieve speeds of 575 m.p.h., about 10% greater than the designed speed.

The HST complex included a one-and two-story combination office/shop building which faced Back River. The one-story wing at the southern end of the building housed the entrance to the test section plenum. The one and one-half story wing at the northern end of the building was set back from the central two-story section of the building and housed the main drive motor.

Design included an igloo-shaped plenum structure around the test section with 1-foot thick walls. The igloo or beehive shape was selected to resist atmospheric pressure and was essentially a low-pressure chamber. Shown in Figure 5 is an interior photo of the original control room underneath the test section.

The narrow test section acted as a venturi nozzle, consequently the airstream, as it moved around the tunnel, created a vacuum in the test chamber. The chamber housed the work station for personnel and as a result of the vacuum, the environment was similar to working at an altitude of 12,000 feet. Test personnel had to wear oxygen masks and enter the chamber through an air lock.

The heat exchanger tower which rises above the tunnel in Figure 2 maintained acceptable operating temperature. The mechanical energy of the 8,000 horsepower fan was absorbed by the airstream as heat. Calculations showed that this energy would raise the temperature within the tunnel ten degrees per second until the heat lost through the concrete tunnel walls to the atmosphere equaled the heat input from the fan. Analysis predicted that this condition would occur about two hours after start-up. In the interim, temperatures in the tunnel would have minimally reached the melting point of steel[2]. Russell G. Robinson designed a ventilating tower which continuously vented a small amount of the heated airstream. The discharged hot air was replaced by cool air pulled in from the outside. The heat bled off with the vented airstream equaled the heat added by the fan. Only about 1 percent of the mainstream airflow had to be vented to maintain acceptable operating conditions.

The closed, circular test section was 8 feet in diameter (2.44 m) and, with a large single-stage, 16-foot diameter, 18-blade fan, driven by an 8,000 horsepower motor, could reach airspeeds of 575 mph (Mach = 0.75). Synchronous speed of the 8,000 horsepower motor (5968-kw) was approximately 900 RPM and speed control was provided by a liquid rheostat system. In the early 1940's, a two-story frame shop/office was added to the southern end of the original office building.

In December 1943, the 8,000 horsepower motor failed. A second stage fan was added and a larger motor supplanted the original. The new motor produced 16,000 horsepower at 820 RPM and had a synchronous speed of 880 RPM. The refurbished tunnel was brought on stream in February of 1945.

With the new fan motor, subsonic Mach numbers up to 0.99 were achieved before choking occurred at or near the model. In order to run higher RPM and generate more horsepower, a Kraemer speed control system was included which allowed the motor to go through synchronous speed to 990 RPM where 22,000 horsepower could be drawn for short periods of time up to about 1/2 hour. A two story Electrical Equipment Building was added behind the main drive motor house to contain the Kraemer system equipment. The electrical controls for the Kraemer system were located on the second story.

Chronology of Modifications on the 8-Foot High Speed Tunnel

Experimental data from the HST generated a series of questions about transonic flight conditions. In an empty tunnel the airstream could reach Mach 1 but when a model was mounted in the test section a "choking effect" restricted speed. Choking occurred, above Mach 0.7, regardless of how fast the technicians made the driving fans turn. Evidently, shock waves formed off the test model, reflected off the tunnel wall, and obstructed accurate measurement of flow characteristics around the model. However, until aircraft reached much higher flying speeds, the choking effect was small and accurately correctable.

These phenomena interfered with development of high-speed aerodynamic data in the late 1930s. However, theoreticians had been aware of the choking problem and the identity of the "sound barrier" long before that time. As early as 1830 the French Scientists Wanzel and Saint-Venant published a mathematical derivation which identified the problem. Their work indicated that a gas flowing through the narrowest part of a constricted duct could not exceed sonic velocity regardless of how much additional driving force was exerted.

From a practical standpoint this did not prevent achieving supersonic flow in a duct. Supersonic speeds could be achieved by expanding the channel area downstream of the throat. The expanded area would accommodate the increased volume required by the airstream as it accelerated above Mach 1. This principle had already found practical commercial use in the late 1880s. The Swedish inventor Carl Gustav DeLaval used it to achieve supersonic velocities in the convergent-divergent nozzles of his steam turbines[4].

In the spring of 1940, Langley engineers built a rig to try to observe the tunnel choking problem. William Orlin used a hydraulic analogy to investigate the problem by building a water channel simulator. While the facility provided data on the dynamics of choking, no practical solution came out of the work[5]. The solution to the choking problem was to come in 1946 with Ray Wright's work with slotted wind tunnels.

With the onset of World War II practical results of high-speed aerodynamic research became vital to the war effort. In December 1941, a few weeks after test pilot Ralph Virden lost his life while test diving the Lockheed P-38, the 8-Foot High-Speed Tunnel (HST) group began an investigation of the stability and control problems of the P-38 using one-sixth-scale models. They found that at about 450 miles per hour, shock waves formed on the upper surface of the P-38's wings. The disturbed airflow made it almost impossible for a pilot to recover the plane from a steep dive. Controls hardened up from the resulting loss of both lift and downwash on the tail, and the pilot could not pull out. Violent buffeting and a strong downward pitching motion tore the tail off Ralph Virden's P-38[6].

The answer to the P-38's dive-recovery problem was developed in March 1942, after less than four months of tests in Langley's 8-Foot HST. Tunnel tests indicated that by installing a wedge-shaped flap on the lower surface of the aircraft's wings, sufficient lift would be retained at high-speeds to enable a pilot to pull the plane out of steep dives. These dive recovery flaps eventually saw service on the P-38 and on the P-47 Thunderbolt, the A-26 Invader, the P-59 Airacomet which was America's first jet and the Lockheed P-80, the first U.S. airplane designed from its inception for turbojet propulsion.

Another critical subject in high-speed tunnel operations was model support arrangements. In 1944 John Becker developed a center plate support which would reduce blockage of airflow. This was a long thin vertical plate mounted across the tunnel diameter and attached to the floor and ceiling of the test section. Wing sections under test were positioned in the plate's plane of symmetry, with half a wing protruding from each side. By the spring of 1945 when the tunnel was set up to operate with its new 16,000 horsepower drive, it had a center plate mount. The 8-foot HST could now produce reliable data to above Mach 0.9. The first assignment for the upgraded facility was testing some Army Air Force models of proposed wing and tail configurations intended for the first generation of high-speed jet bombers.

The center plate support was useful for studying high-speed aerodynamic forces and pressures affecting isolated wings. It was not effective for testing the performance of wing and body combinations or complete aircraft configurations.

The Langley engineers overcame plate support limitations with the development of a "sting" support system. The model was supported from behind by a rod, commonly called a "sting," which protruded from a vertical strut extending through the airstream of the test section. Models of the XS-1 and D-558-1 were tested using sting supports in the spring of 1946. Langley used the sting support system in the spring of 1946 to test models of the Bell XS-1, the first plane to fly supersonically and the Douglas Aircraft Company's D-558-1[8] in the 8-Foot HST. The sting mounting system gave reliable data up to Mach 0.92[7].

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[8]Douglas proposed to build six transonic research aircraft for the navy in 1944. The experimental planes were to gather data at speeds ranging from Mach .89 to Mach 1. The results of this test program were used to construct a combat version of the D-558.

In 1946 experiments guided by a Langley physicist, Ray H. Wright indicated that interference due to solid blockage in wind tunnels operating at subsonic speeds could be minimized by placing slots in the throat of the test section. This concept became known as the slotted throat or slotted-wall tunnel. Wright was attempting to eliminate an effect known as wall interference and developed it as a way to get rid of wall interference[f] at subsonic speeds.

Wright was developing a theoretical understanding of wall interference in the 8-Foot HST, which was then having a new 16,000 horsepower motor installed for Mach 1 capability[8].

The problem of wall interference dated back to the early days of wind tunnel technology. Aerodynamicists had considered how accurately airflow confined within solid wooden or metal walls could simulate actual conditions of flight in free air as early as 1870. At most, the distance between tunnel walls and scale-model aircraft was only a few feet. Air surrounding full-scale aircraft was disturbed to distances several times that distance. It was impossible, in a solid walled test chamber, for airflow to stream naturally over and near the models. The walls suppressed the flow streamlines and produced deceptive aerodynamic effects. Reducing model sections from five percent to one percent of the test section area raised the choking speed but simultaneously lowered the Reynolds number. This effect only increased the dissimilarity between simulated and actual flight. Earlier experiments at Edgewood Arsenal eliminated walls completely but these open jet tunnels deformed the airstream in other ways.

One of Wright's reports contains the genesis of the slotted tunnel concept: "since the interference velocities due to . . . walls are of opposite signs with free and solid boundaries, opposite effects might be so combined in a slotted tunnel as to produce zero blockage." His contribution was combining the corrections for the different types of tunnel throats to totally eliminate the need for any corrections[9].

The concept could also be traced back to theoretical papers by Prandtl and Glauert in Germany during the 1920s. Considerable work on choking was done by the British, Italians, Japanese, and Germans[g] during World War II. Because

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[f]Wall interference is the mutual effect of two or more meeting waves or vibrations of any kind reflecting off solid boundaries.

[g]Hansen (1987:318) comments: "Most noteworthy was the work by Carl Wieselberger in Germany. In 1942, Carl Wieselberger suggested a specific configuration with 46 percent of the perimeter open as a means to reduce the blockage effect in certain German high-speed tunnels."

of wartime secrecy, NACA engineers did not know about the German developments, which occurred in 1942, until 1944[h].

The repowering and reconfiguration of the HST that occurred in 1945, with its closed throat test section and the new sting support system installed in 1946 was not producing reliable data above Mach 0.92. Preliminary results in the reconfigured facility produced Reynolds numbers that were lower than expected. In addition, it appeared that procurement delays would hold up completion of a planned 16-foot slotted tunnel. The quickest and cheapest way to apply the new slotted-wall concept was to convert the operational 8-foot HST to a slotted test section configuration. In addition, all fabrication and installation could be done at Langley. In the spring of 1948 NACA management decided to convert the 8-Foot HST to a slotted throat configuration. Altering the 8-Foot HST became a top priority.

In late 1948, the altered 8-Foot HST achieved Mach 1+ with a slotted throat, but the flow was unacceptably turbulent and irregular. Development activity focused on forming the precise slot configuration for smooth transonic flow. But existing theory had taken the design as far as it could; the work called for experienced metal craftsmen and an empirical approach[10].

Final 'sculpting' and shaping of the slots by hand was accomplished by physicist Ray Wright and engineers Virgil S. Ritchie and Richard Whitcomb. By hand contouring the slots with painstaking effort they refined the details of the slotted throat until they achieved smooth transonic flow distributions. The slotted test sections would eliminate closed tunnel choking limitations and permit operation at low supersonic speeds.

Reconfiguration of the 8-foot HST as the 8-foot Transonic Tunnel (TT)

In 1950, the 8-foot HST was reconfigured to accommodate a twelve-sided slotted test section shown in figure 7. Its fan blades were replaced and a new drive train installed[11]. The facility was redesignated as the 8-Foot Transonic Tunnel (8-foot TT). The reconfigured tunnel went on-stream on October 6, 1950 and began regular transonic operation.

As soon as the slotted-throat section was calibrated, the engineers initiated detailed studies to determine what happened in the flow field around wing and body combinations at transonic speeds. Their instruments and mechanisms included a tunnel balance, which was the standard means of measuring the aerodynamic forces of lift, drag and pitch on a model. In addition, the model was designed with orifices sensitive to pressures at

[h]The information on Axis Powers research was transferred by Major Antonio Ferri who had directed research at the *Galleria Ultrasonora* (supersonic tunnel) at the Italian aeronautical research center at Guidonia. Ferri had been working for the U.S. Army's Office of Strategic Services (OSS) and delivered numerous top secret technical reports into the hands of the Allied Powers (Hansen 1987:319).

various points on its surface; measurements at these points allowed calculation of local velocities. The engineers brought back tuft surveying which had been used in the early days of wind tunnel testing. Tufts of cloth were attached in various places on a model surface, observation during tests indicated if the flow was smooth or disturbed. They also employed schlieren photography, a method for visualizing aerodynamic shock waves. While the test methods and instrumentation were conventional and had been used for many years, their combined use gave results that indicated actual transonic drag patterns varied significantly from theoretical predictions.

The schlieren photographs indicated two new types of shock waves; one that built up as the fuselage and wings began forcing more air out of the way, and another near the trailing edge of the wing. Compared to the size of the wing and body combination being analyzed, the disturbed area of air was much larger than previously understood. The losses occurring from the new shock waves possibly accounted for the sharp rise in drag occurring in transonic flight[i].

A systematic series of wing and body combinations were tested in the 8-Foot HST starting in November 1951. Test models included swept, unswept, and delta wings. Fuselages with various amounts of curvature in the region of the wing were also tested. The program's purpose was to quantify the drag caused by the interference of wing and fuselage shapes at transonic speeds. Data analysis resulted in two important new ideas. The first was that even minuscule variations in the shape of the fuselage could lead to significant changes in the drag of the wing. The second was that to determine transonic drag, the drag of the wing and the drag of the body had to be figured as a whole. The wing and fuselage were a common interactive aerodynamic system.

Richard Whitcomb perceived that ideal streamlined body for supersonic flight was not a function of the diameter of the fuselage alone; transonic drag rise was originated by the total cross-sectional area of the fuselage, wings and tail. He pictured the deviation of the streamlines as they passed across the nose, along the body, and finally up over the wings, visualizing locations where air was being displaced most violently and came up with the notion that if air could be displaced more gently, the waves and drag would diminish and the aircraft could pass through the transonic zone with less difficulty. This was accomplished by compressing the waist of the fuselage.

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[i]The conventional way to design high-speed aircraft was to base it on the bullet-shaped fuselage originally suggested by Ernst Mach. These shapes produced less drag in flight than any other known shape. However, controlled, manned aircraft required wings and a tail; they could not reach the ideal bullet-like shape. Richard P. Hallion, historian of supersonic aircraft, reported: "They gave the fuselage a pointed nose, then gradually thickened the body-that is, increased the cross-sectional area-until the fuselage reached its maximum diameter near the middle." The diameter of the fuselage was decreased only at the tail. This design characteristic became known as the "rule of thumb" (Hansen 1987:333).

The reduced fuselage diameter allowed streamlines which were being driven aside abruptly to have room for smoother transition. The "wasp waist" design would reduce the violent shock patterns experienced in conventional design. Whitcomb's concept was greeted with some skepticism by his colleagues, however, he was allowed to pursue extensive testing of what became known as the "area rule."

During the summer of 1952, models of a new supersonic fighter-interceptor, Convair's YF-102 was being tested in the 8-Foot TT. Data indicated that the aircraft could not fly supersonically. The transonic drag was higher than anticipated. The plane had a bullet-shaped fuselage, knife-edge delta wings, the Pratt & Whitney J-57 engine and everything else that contemporary engineering thought necessary for sustained supersonic flight. Convair was well advanced in setting up production lines to mass produce F-102s that probably would not meet the supersonic flight specification.

In mid-August 1952, a team of Convair engineers observed discouraging YF-102 tests performed in the 8-Foot TT. Whitcomb revealed his discovery of the area rule for mitigating transonic drag to the Convair team.

The Convair engineers were not convinced that the area rule theory was correct. They also did not have much faith in the wind tunnel data that indicated the YF-102 could not go supersonic in level flight. However, the wind tunnel results were confirmed by test flights of the prototype in late 1953 and early 1954.

Whitcomb worked with Convair to apply the area rule to the YF-102. By May of 1953 wind tunnel tests indicated significantly less drag. However, supersonic performance was still questionable. The YF-102 was recontoured and modified according to Whitcomb's area-rule. The modified aircraft, designated the YF-102A, theoretically met the air force specifications for supersonic flight by October of 1953. The air force halted Convair's assembly line and recommended that the company retool for manufacturing the YF-102A.

A new prototype was built in less than seven months. The YF-102A was given a sharper nose and canopy, wasp waist, tail fairings, and a more powerful version of the J-57 engine. On December 20, 1954 the YF-102A "slipped easily past the sound barrier and kept right on going." Whitcomb's area rule had aided boosting the plane's top speed by about 25 percent. The exceptional performance persuaded the air force to contract with Convair for over 1000 F-102As. An advanced version of the F-102A which was designated the F-106 Delta Dart, was an essential component of America's air arsenal into the early 1980s.

Other aircraft manufacturers quickly followed Convair's lead. Chance Vought's F-8U carrier-based interceptor was redesigned using the area-rule. While much of the early area-rule work centered on the Convair F-1102A, Grumman built the first area-rule-based aircraft to fly supersonically. Grumman's F9F-9 Tiger went through the sonic barrier without an afterburner on

August 16, 1954. Lockheed's F-104 Starfighter, an area-rule designed aircraft was the first jet to exceed Mach 2 in April 1956.

In spite of attempts at secrecy, the discovery of the area-rule was so important an aerodynamic breakthrough that it became known to the public in less than a year. Articles in the trade and popular press revealed the new aircraft design which was popularly called the "Coke Sottle" or "Marilyn Monroe." NACA officially released news of the area rule in September 1955.

The National Aeronautic Association awarded Whitcomb the Collier Trophy for the greatest achievement in aviation in 1955. The tribute to Whitcomb read:

> the " . . . area rule is a powerful, simple, and useful method of reducing greatly the sharp increase in wing drag heretofore associated with transonic flight, and which constituted a major factor requiring great reserves of power to attain supersonic speeds." The concept was used in the design "of all transonic and supersonic aircraft in the United States."

The experience accumulated in developing, refining and testing of slot shapes for the 8-foot TT was valuable in designing slots for transforming the Langley 16-foot High Speed Wind Tunnel to a slotted-wall, transonic configuration. Measurements defining the precise shape of slots in the 8-Foot TT helped get the 16-foot tunnel operational only three months after the 8-foot TT went on stream[12]. The last major change in the 8-Foot TT occurred in 1957 when fiber reinforced epoxy blades replaced the wooden fan blades.

A new tunnel, the 8-Foot Transonic Pressure Tunnel (TPT) was designed and built adjacent to and west of the 8-Foot TT. It went on stream in 1952 and briefly shared some electrical facilities with the 8-Foot TT. Operation of the two 8-foot transonic facilities overlapped until the 8-Foot TT was deactivated in 1961[13].

After deactivation of the 8-foot TT, its 16,000 horsepower motor, drive shaft, and fans were kept in operational condition. Scheduled maintenance included rotation of the drive shaft and fans. In 1976 it was decided that scheduled rotation was unnecessary. The fan blades, hub, nacelle, and shaft, and the turning vanes immediately upstream of the fan were removed and sent to Wright Patterson AF8 for use in the construction of a new facility in the early 1980s. The 16,000 horsepower motor (fig. 4(b)), remains in place in room 115, Building 641. In 1985 the 8-foot TT was designated as a National Historic Landmark[14]. Technical data on the 8-foot HST and TT have been abstracted from NACA reports and are included in the appendix.

Conclusion:

Several aerodynamic design concepts were generated from tests performed in the 8-Foot HST as it was originally configured. Researchers were able to delineate the specific stability and control problems encountered in high-speed dives. Practical aircraft products to result from the studies included a dive recovery flap, high-speed low-drag engine cowlings, a new family of air inlets for jet-propelled aircraft and designs for 500+ mph propellers[15].

The truly outstanding contributions from this facility came after its conversion to a slotted-throat design. In addition to management's caution in committing to unproven technology, the proponents and inventors had to overcome complex technical problems inherent in any developing technology. The evolution of efficient designs for supersonic aircraft can be traced to this pioneering facility.

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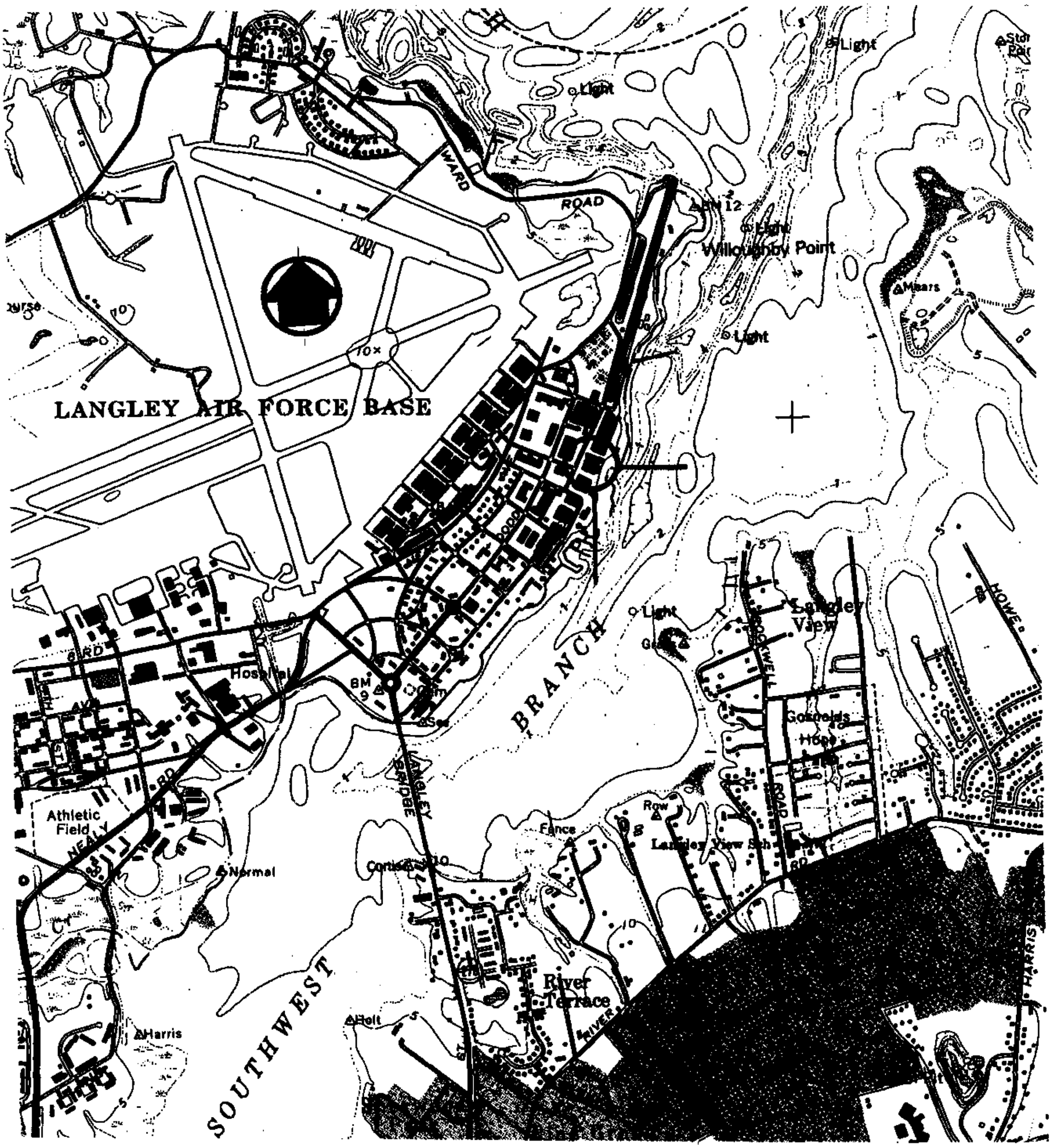

Figure 1 - Location Map
Langley Research Center 8-Foot High Speed Wind Tunnel/Transonic Tunnel
Quadrangle: Hampton, Virginia - 1:24000

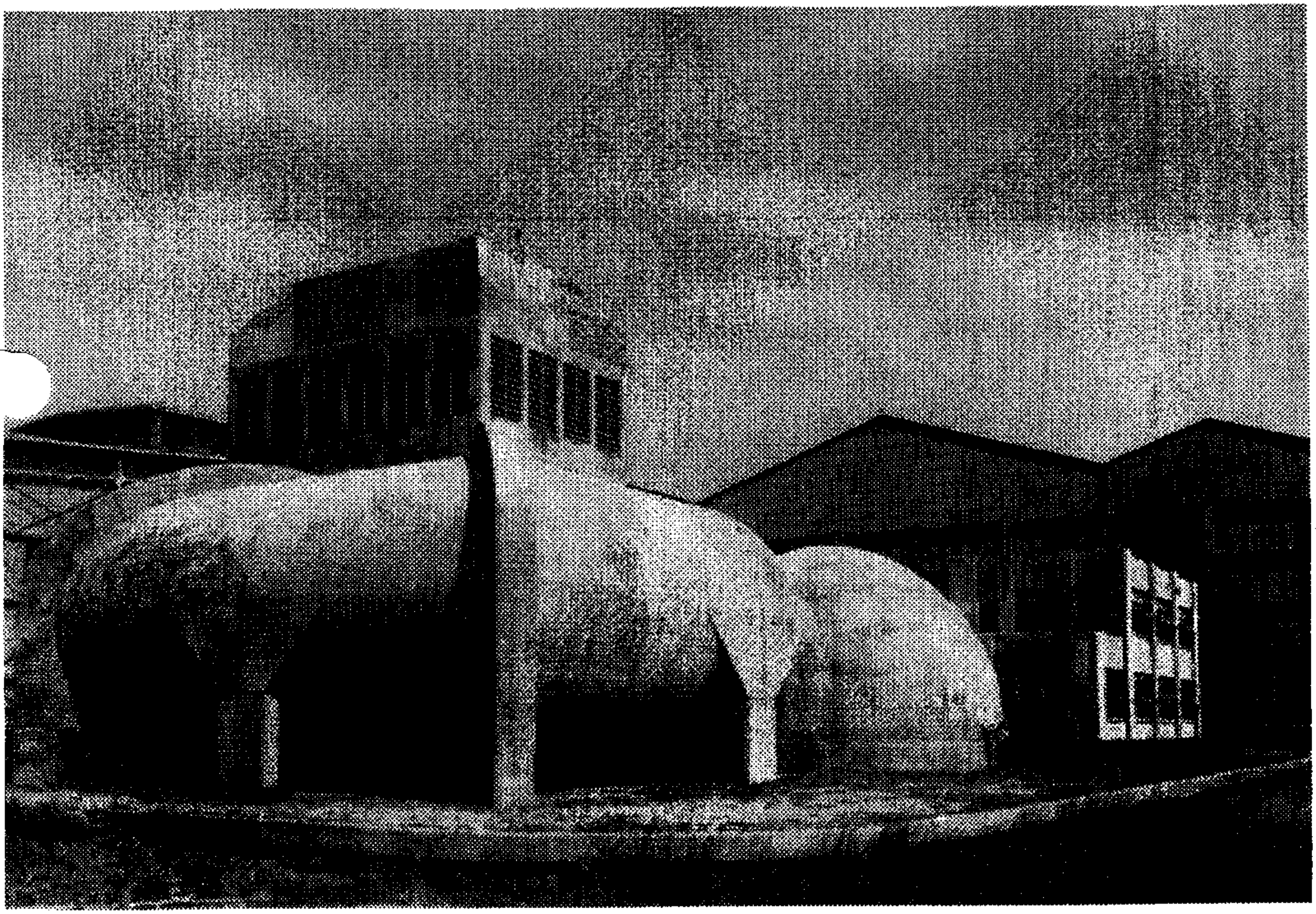

Figure 2 - View Northwest - 1936
Langley Research Center 8-Foot High Speed Wind Tunnel/Transonic Tunnel
(Note Heat Exchanger Tower at left center) NACA 12000.1

Figure 3 - View West - 1936
Langley Research Center 8-Foot High Speed Wind Tunnel/Transonic Tunnel
NACA-LAL 12470

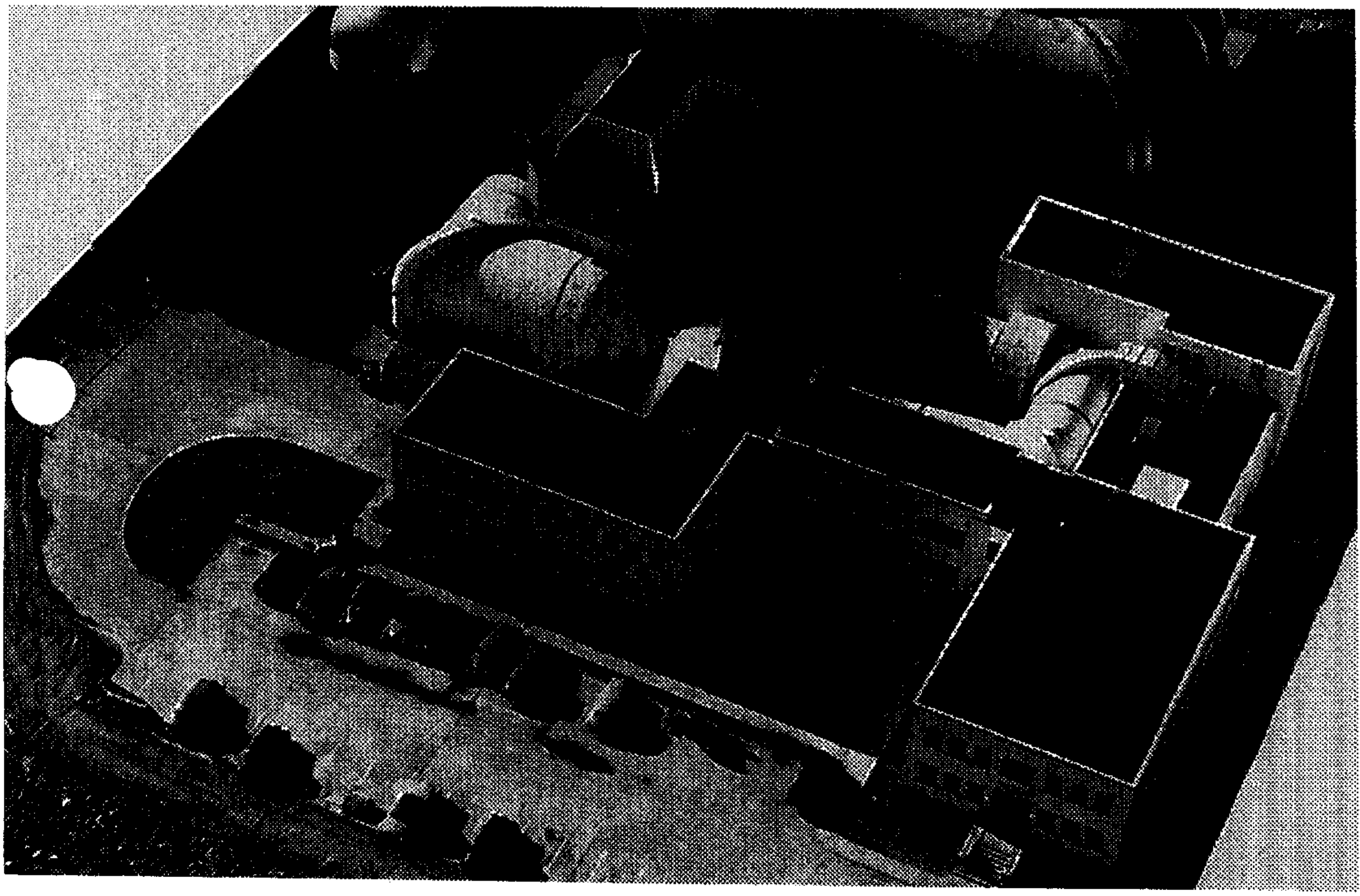

Figure 4 - Aerial View Southwest - 1950s
Langley Research Center 8-Foot High Speed Wind Tunnel/Transonic Tunnel L-78271

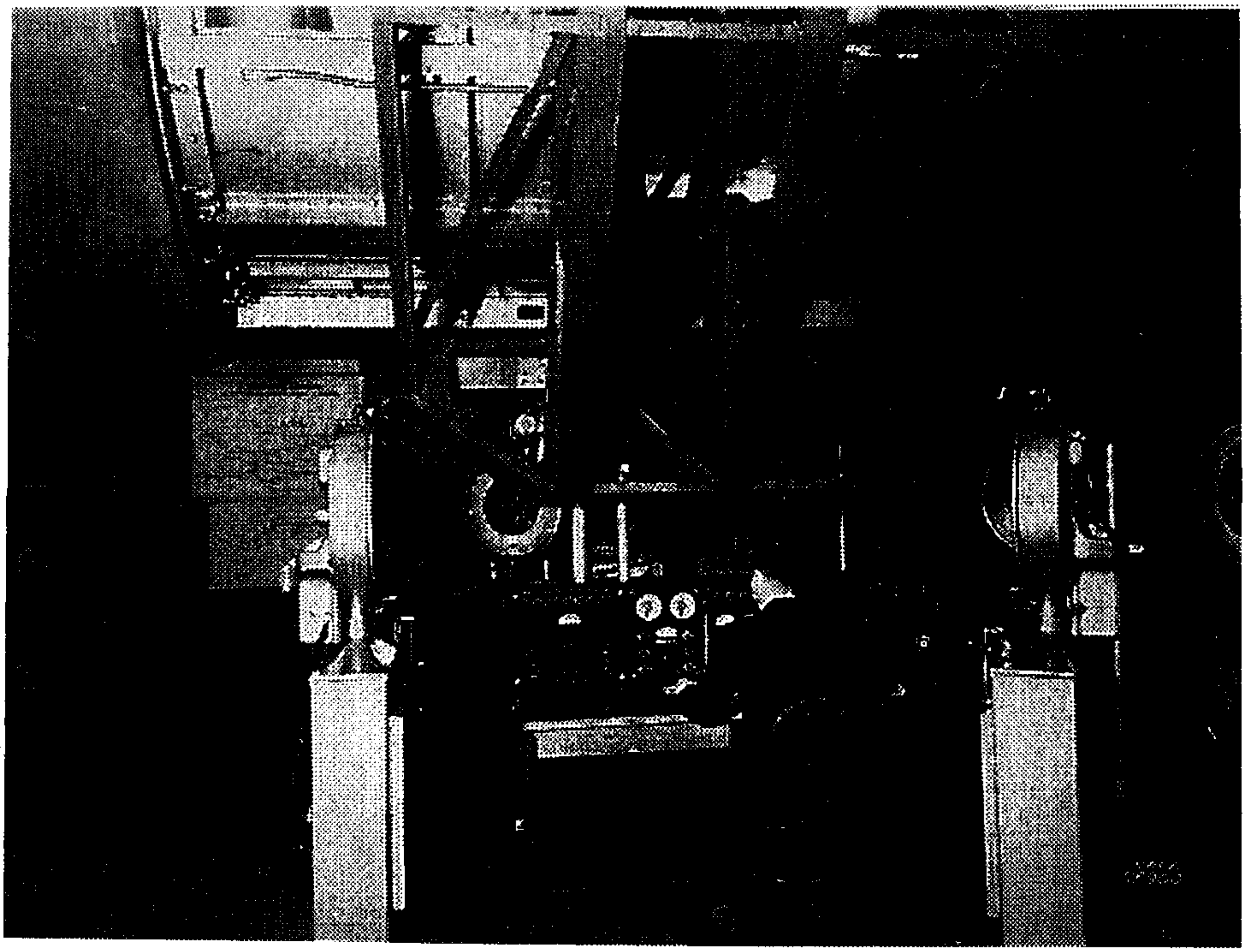

Figure 5 - Test Section and Control Console - 1930s
Langley Research Center 8-Foot High Speed Wind Tunnel/Transonic Tunnel NACA 16900

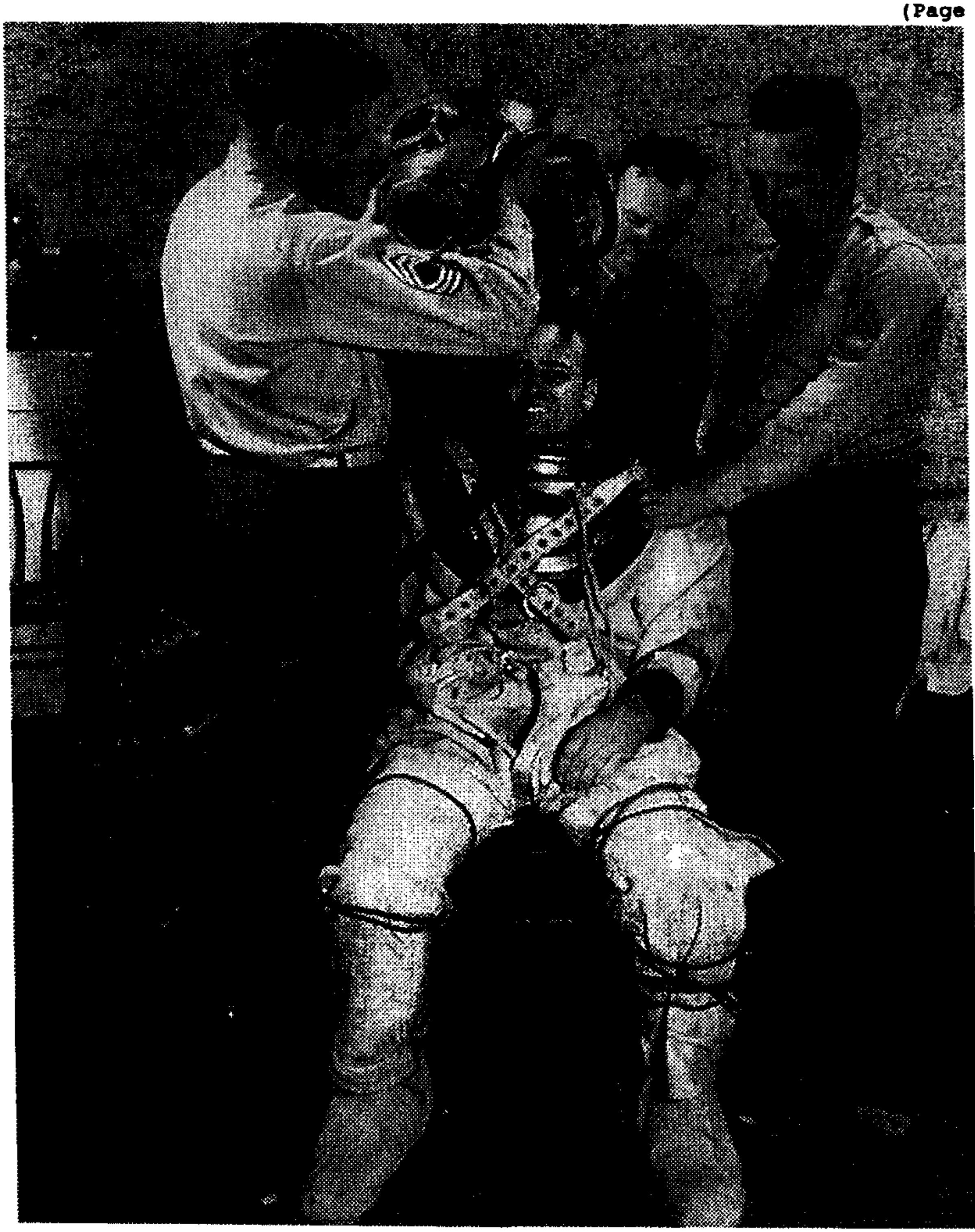

Figure 6 - Addition of slots which opened into the 8-Foot TT's beehive-shaped test chamber created hazardous levels of pressure, temperature, and noise. Designer Ray Wright had to wear a diving suit to enter the chamber. L-64110

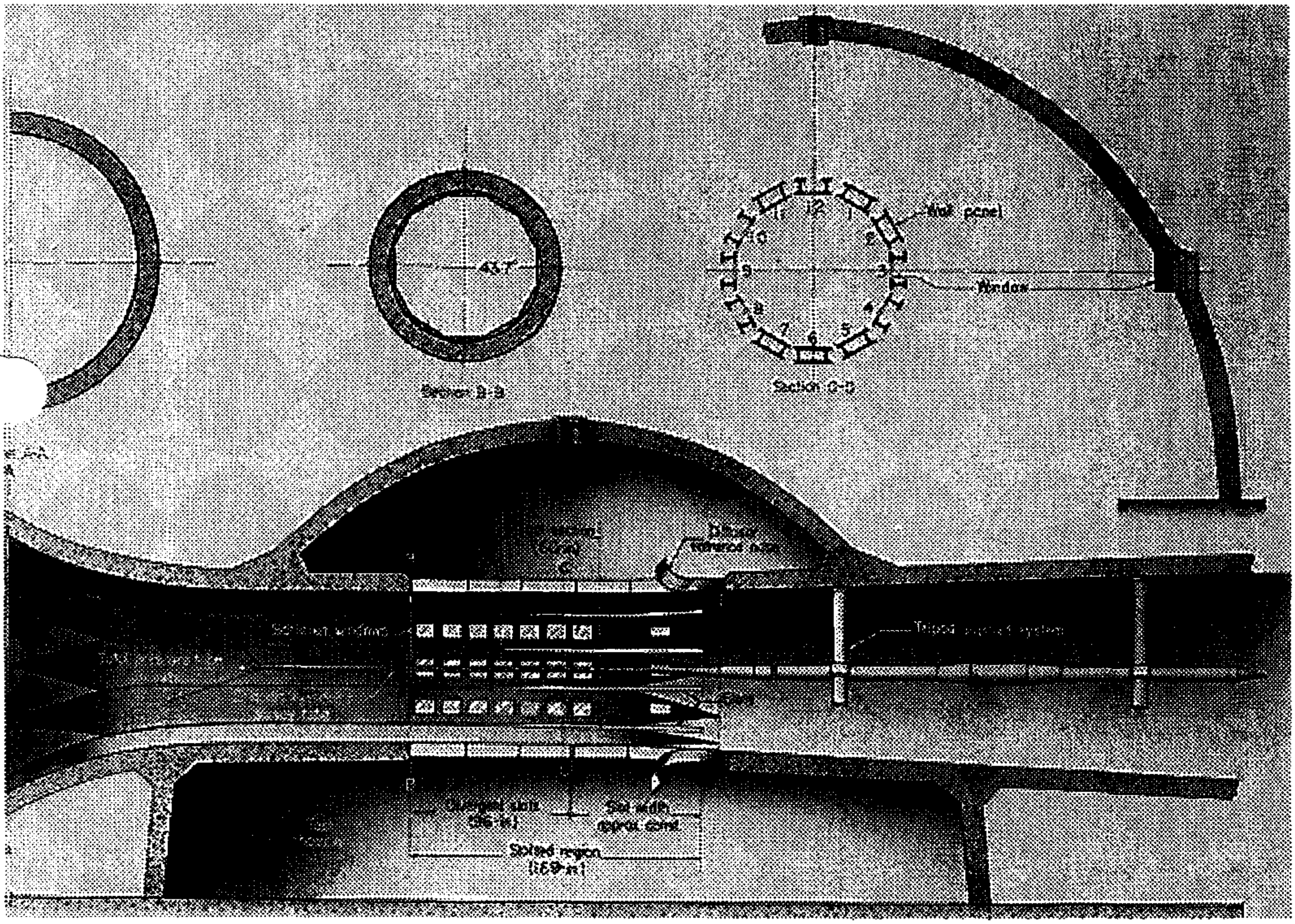

Figure 7 - Views of throat region of 8-Foot HST/TT showing slotted test section, cylindrical survey tube and support system. L-71020

APPENDIX

GENERAL DESCRIPTION OF THE 8-FOOT TRANSONIC TUNNEL (1950-1961)[1]

The tunnel is a single-return, atmospheric type with cooling accomplished through air exchange. The amount of air exchanged can be controlled with adjustable vanes.

The fan section of the tunnel is made up of two tandem rotors having 17 fixed-pitch blades in each. Prerotation vanes upstream direct the air into the rotors and counter rotation vanes downstream reduce the rotation of the air mass leaving the fans. The two rotors are mounted on the same shaft and are driven by a 22,000-horsepower motor. The motor-speed control is variable from 0 to 990 rpm.

TEST SECTION

The test section of the Langley 8-foot transonic tunnel is dodecagonal in cross section and has a cross-sectional area of about 43 square feet. Longitudinal slots are located between each of the 12 wall panels to allow continuous operation through the transonic speed range. The slots contain about 11 percent of the total periphery of the test section. Six of the twelve panels have windows in them to allow for schlieren observations. The entire test section is enclosed in a hemispherical shaped chamber.

TEST CONDITIONS

The Mach number in the test section can be continuously varied from 0 to about 1.2, the higher value being somewhat dependent on model size. The Mach number distribution is reasonably uniform throughout the test region length of about 5 feet. The maximum deviations from the average stream Mach number are of the order of 0.010 at the highest test Mach number.

The stagnation temperature of the tunnel air can be controlled within limits by the vanes and blocks in the air-exchange tower. Generally, stagnation temperatures around 1500 F are maintained. The maximum stagnation temperature permissible is 1800 F, this limit being imposed because of some of the tunnel equipment.

Since the tunnel operates around atmospheric stagnation pressure, the Reynolds number is about 3.5 to 4.0 million per foot at the higher test Mach numbers.

MODEL-SUPPORT SYSTEM

The sting-type model-support system is used in the Langley 8-foot transonic tunnel. The sting is attached to a tapered support strut which in turn is connected downstream to a motor-driven metal arc. The system is designed so as to keep the center of gravity of the model on the center line of the tunnel throughout an angle-of-attack range from -10 to +14 degrees. For angles of attack outside of this range a series of angular couplings are provided. A large range of yaw angles can be obtained by suitable model or coupling rotation. In addition to angular displacement the model-support system can be moved axially about 26 inches to position the models in different parts of the test section. The load limits on the model support are 2,000 pounds of normal force, 400 pounds of axial force, and 175 pounds of side force.

MODELS

Generally steel models with wing spans of the order of 2 feet are used for investigations in the Langley 8-foot transonic tunnel. The models can be instrumented for pressure-distribution measurements or strain-gage-balance measurements. Since the bodies used are small (3 to 4 inches in diameter), space is not sufficient to allow for extensive pressure measurements in conjunction with the strain-gage-balance measurements. Pressure distributions give much detailed information about the configurations and can be integrated to give either overall forces and moments or forces and moments on component parts. The strain-gage balances generally give overall forces and moments; however, other strain gages can be mounted at various locations on the model to measure forces and moments on component parts and to get an indication of the buffet stresses.

INSTRUMENTATION

Balances

A variety of strain-gage balances are available for use in the models. Generally, six components of force and moment can be measured with these balances and different balances can be used for different load ranges. A typical balance would be about 6 to 10 inches long with 1 to 2.5 square inches of cross-sectional area, and would sustain maximum loads of about 1,200 pounds normal force, 2,000 inch-pounds pitching moment, 85 pounds axial force, 1,000 inch-pounds rolling moment, 1,000 inch-pounds yawing moment, and 250 pounds side force. For investigation of drag at low lift, balances are available which have lower load ranges for axial force and permit more accurate drag measurements.

Manometers

Three 100-tube tetrabromethane-filled manometers are available for the measurement of steady pressures. The working height is 10 feet, and the scales have 0.10-inch divisions. Recording is by photography.

Data Recording and Reduction

The data recording and reduction equipment used for handling steady force and pressure information at the Langley 8-foot transonic tunnel is similar to that described for the Langley 16-foot transonic tunnel. Very little dynamic data recording equipment, however, is available.

Flow Visualization

A schlieren apparatus is used in the 8-foot transonic tunnel for visual flow studies. It is a single-pass system using two 12-inch parabolic mirrors. The system is mounted on large movable support structures which permit observations at any desired test section window in the horizontal plane, or in a plane 300 from the horizontal. A spark source is used for photographic recording with a still camera. The entire system is located within the test chamber and is operated by remote control.

CHRONOLOGY

LANGLEY RESEARCH CENTER - 8-FOOT HIGH SPEED TUNNEL/TRANSONIC TUNNEL

The original High-speed-tunnel concept was developed in November of 1934 by Eastman Jacobs.

The 8-Foot High Speed Tunnel became operational on March 28, 1936.

In December 1941, the 8-Foot High-Speed Tunnel (H8T) group began an investigation of the stability and control problems of the P-38 using one-sixth-scale models.

In the early 1940's, a two-story frame shop/office was added to the southern end of the original office building.

The center plate support system for models was developed in 1944.

The 8-Foot High Speed Tunnel was repowered (Mach I capability); the new motor produced 16,000 horsepower at 820 RPM and had a synchronous speed of 880 RPM. The center plate support system was installed. The refurbished tunnel was brought on stream in February of 1945. The 8-foot HST could now produce reliable data to above Mach 0.9.

A new "sting" model support system was developed and used in the spring of 1946 to test models of the Bell XS-1, the first plane to fly supersonically and the Douglas Aircraft Company's D-558-1 in the 8-Foot HST. The sting mounting system gave reliable data up to Mach 0.92.

A Mach 1.2 contoured nozzle was installed in December 1947.

In late 1948, the altered 8-Foot HST achieved Mach 1+ with a slotted throat.

A reconfigured slotted-throat test section was installed in 1950. The 8-Foot High Speed Tunnel was redesignated as the 8-Foot Transonic tunnel. Transonic operation was achieved October 6, 1950.

In November of 1951 various wing and body combinations tested. Results were not as predicted. The interactive nature of wing and body drag at transonic speeds was discovered.

During the summer of 1952 tests in the 8-foot transonic tunnel predicted that Convair's YF-102 would not fly supersonically.

August 1952 - Richard Whitcomb discloses his discovery of the "area rule" to Convair engineers. Application of the area rule to the Convair YF-102 and several other aircraft designs facilitates supersonic flight.

September 1955 - NACA releases news about the discovery of the "area rule."

1955 - Richard Whitcomb receives Collier Trophy for discovering the area rule.

1957 - Fiberglass blades replace wooden fan blades in the 8-Foot TT.

1961 - The 8-foot TT was deactivated.

1985 - The 8-HST/TT was named a National Historic Landmark.

1 Abstracted from: Characteristics of Nine Research Wind Tunnels of the Langley Aeronautical Laboratory. Washington, D.C.: National Aeronautics and Space Administration, 1981.

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